Comisión Nacional del Agua—National Weather Service Project to
Transfer the National Weather Service River Forecast System to México:
Project Accomplishments and Future Tasks 1996-2005

1.0 Executive Summary

The Secretaría de Medio Ambiente, Recursos Naturales y Pesca (SEMARNAP) and the US National Oceanic and Atmospheric Administration (NOAA) signed a five-year agreement on meteorological and hydrological cooperation on May 13, 1996 at the US Embassy in Mexico City. Under this agreement, the Comisión Nacional del Agua (CNA) and the National Weather Service (NWS) have cooperated on a multi-year project that transfers NWS river forecasting and associated technologies to Mexico. The project is supported by the World Bank through the Programa de Modernización del Manejo del Agua (PROMMA.)

The principal goal of CNA-NWS project is to provide CNA staff with the training and practical experience needed to implement river forecasting and associated technologies that are needed to mitigate the loss of life and property caused by floods and to improve the management of water resources for nation's economic well being. Toward this goal the project is assisting CNA decentralize authority to Regional offices via establishment of Regional River Forecast Centers, modernizing Regional hydroclimate monitoring networks, establishing modern hydroclimate database management systems, strengthening data and information communications between Mexico City and Regional offices, introducing new meteorological technologies to support water-resources management, and establishing flash-flood warning systems. From late 1996 and continuing through 2000, the CNA and NWS have implemented river forecasting and associated technologies in the Ríos Fuerte, Yaquí, Bravo, and Pánuco basins in the CNA Pacifico Norte, Noroeste, Río Bravo and Golfo Norte Regions**,** respectively. In anticipation of the renewal of the SEMARNAP-NOAA agreement, during 2001 through 2005 the two organizations intend to continue this implementation in additional river basins in these CNA Regions, as well as the Ríos Nazas and Aguanaval basins in the Cuencas Centrales del Norte Region.

A key area of cooperation during 1999 and 2000 has been in the Río Bravo basin. The Comisión Internacional de Límites y Aguas (CILA) and the International Boundary and Water Commission (IBWC) are cooperating on the establishment of real-time exchange of hydroclimate data and associated information between the two countries. The purpose of this effort is to improve Río Bravo forecasting by Mexican and US forecast centers in Monterrey, Nuevo León, and Fort Worth, Texas, respectively.

Since the project's inception new and more powerful technologies have emerged both in Mexico and the US. The CNA-NWS project provides the opportunity to cooperate on the implementation of such technologies and, thus, should serve to further improve flood forecasting and water management. CNA staff capacity development is key to sustaining these technologies after the conclusion of the project. Numerous CNA engineers, from Mexico City, selected Regions and CILA, have worked side-by-side with NWS engineers in implementing the systems cited above.

2.0 Introduction

The Secretaría de Medio Ambiente, Recursos Naturales y Pesca (SEMARNAP) and the US National Oceanic and Atmospheric Administration (NOAA) signed a five-year agreement on meteorological and hydrological cooperation on May 13, 1996 at the US Embassy in Mexico City. Under this agreement, the Comisión Nacional del Agua (CNA) and the National Weather Service (NWS) agreed in principle to a multi-year project that transfers NWS River Forecasting System (NWSRFS) and associated technologies to Mexico. The principal goal of CNA-NWS project is to provide CNA staff with the training and practical experience needed to implement river forecasting and associated technologies that are needed to mitigate the loss of life and property caused by floods and to improve the management of water resources and economic well being. Project activities are defined by annual agreements, prepared on a calendar-year basis. The project is supported by the World Bank through the Programa de Modernización del Manejo del Agua (PROMMA.)

To facilitate the transition to a new Presidential administration in México, this report has been prepared by the CNA and NWS. It documents the accomplishments of the CNA-NWS project from 1996 through 2000, includes the recommendations and assumptions underlying the planned 2001 - 2005 project, and contains a brief discussion of the continuing project. .

The NWSRFS is used operationally in the US to forecast floods and river flows to mitigate loss of life and property. The NWSRFS and associated technologies will continue to be improved by the NWS to support domestic flood forecasting and water management needs. Such improvements will be shared with CNA counterparts and implemented whenever technically feasible. The CNA-NWS project provides Mexican counterparts with capacity development and on-the-job experience needed to implement the NWSRFS in selected river basins throughout México that represent a variety of climatic and hydrologic settings. Capacity development of CNA staff is intended to assist CNA implement the forecast system in other river basins in México.

A major contribution of the project in 1999 and 2000 is the strengthened cooperation by the US and México in forecasting and management of the Río Bravo, their common boundary river. The Comisión Internacional de Límites y Aguas (CILA) and the International Boundary and Water Commission (IBWC) are cooperating on the establishment of real-time exchange of hydroclimate data and associated information between the two countries. The purpose of this effort is to improve Río Bravo forecasting by Mexican and United States forecast centers in Monterrey, Nuevo León, and Fort Worth, Texas, respectively.

The principal partner of the NWS in this project is the CNA Gerencia de Aguas Superficiales e Ingeniería de Ríos (GASIR), which is responsible for monitoring and managing Federal rivers

and reservoirs in México. From 1996 through 2000, the NWS[1] and GASIR have implemented the NWSRFS in the Ríos Fuerte, Yaquí, Bravo, and Pánuco basins. In order to implement these basins, CNA engineers were trained in hydroclimate data analysis, model calibration, NWSRFS operation, and NWSRFS maintenance. Training of CNA engineers and cooperative development of these systems is essential to supporting the technology as CNA assumes operational responsibility for them. To assist CNA support of the systems, the NWS also is translating NWSRFS manuals into Spanish.

During the last four years, GASIR and NWS also have evaluated and implemented associated technologies in support of NWSRFS implementation. GASIR and GSMN operate data collection network in México and these networks need to be strengthened and integrated with the forecast system. GASIR and GSMN are in the process of automating their networks and their data will be used to enhance operation of the forecast system in the basins where they both exist. Two potential additional sources for estimation of precipitation, using radar and satellite also were evaluated. These evaluations were assisted by the Instituto Mexicano de Tecnología del Agua (IMTA).

One of the principal goals of PROMMA is to decentralize the management of water in México. Towards this goal, the NWS assisted CNA begin to establish Regional River Forecast Centers (RRFC's) in two CNA regions and developed database and Internet-based systems to store and exchange information and data between RRFC's and CNA headquarters. In 1999, the CNA Noroeste Region RRFC in Hermosillo, Sonora, started to test database and data transfer systems and operate the Ríos Fuerte and Yaquí NWSRFS. The river forecast systems are called Sistema de Pronóstico en Ríos de la CNA (SPRCNA) when they became operational by CNA.

To strengthen the capacity of CNA, the NWS conducted hydrologic study tours to the United States for CNA managers. The NWS also conducted workshops on the NWSRFS, application of Geographic Information System (GIS) technology for flood inundation mapping, and reservoir Decision Support Systems (DSSs), which were attended by CNA staff, and several US government and private organizations. In 2000, GASIR and NWS are developing the use of GIS to visualize the extend of flooding in the Tampico area. In addition, GASIR and NWS compared current forecast models in México to models in the NWSRFS to evaluate the advantages and benefits of the models. The schedule of major tasks that were undertaken in 1996-2000 is shown in Figure 1.

During the next five years, the NWS will continue to provide technical support to CNA to operate SPRCNA's and to implement additional systems in selected river basins, further

[1]In this document, NWS refers to the NWS team of government employees and contractors who assisted the NWS.

ID	Task Name
1	**3.1 Sistema Pronostico en Rios de la CNA (SPRCNA)**
2	3.1.1 Rio Fuerte SPRCNA
3	3.1.2 Rio Yaqui SPRCNA
4	3.1.3 Rio Bravo SPRCNA
5	3.1.4 Rio Panuco SPRCNA
6	**3.2 Development and Implementation of Advanced Technologies related to River and Flood Forecasting**
7	3.2.1 Precipitation Estimation
8	3.2.1.1 Use of Radar
9	3.2.1.2 Use of Satellite Imagery
10	3.2.2 Flood Inundation Mapping using GIS
11	3.2.3 Hydroclimate Database Management and Regionalization
12	3.2.4 Dynamic Flow Routing using FLDWAV
13	**3.3 Regional River Forecast Centers**
14	3.3.1 Noroeste Region
15	3.3.2 Rio Bravo Region
16	**3.4 Capacity Building and Development of Human Resources**
17	3.4.1 SPRCNA Training
18	3.4.2 Study Tours and Water Management Workshops
19	**3.5 Other**
20	3.5.1 NWSRFS Document Translation
21	3.5.2 GASIR/NWSRFS Model Comparison
22	3.5.3 Border Data and Information Exchange
23	3.5.4 Coordination with Other Related PROMMA Projects

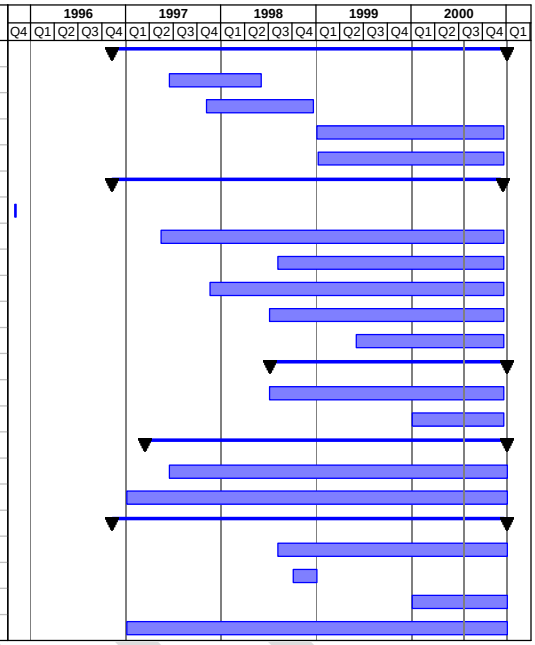

Figure 1. CNA-NWS Project tasks, 1996-2000.

strengthen the expertise and capacity in CNA to sustain these technologies, complete the activities concerning GIS, satellite, radar, and database systems, and implement hydraulic analysis for large releases from reservoirs. The NWS and CNA also will develop prototype flash flood guidance for selected areas to complement the large river basin forecast systems already developed. In support of end-to-end forecast process, the NWS will assist CNA implement a warning process for distribution of forecasts obtained from NWSRFS and flash flood guidance to population at risk and general public. The schedule of major tasks that will be undertaken in 2001-2005 is shown in Figure 2.

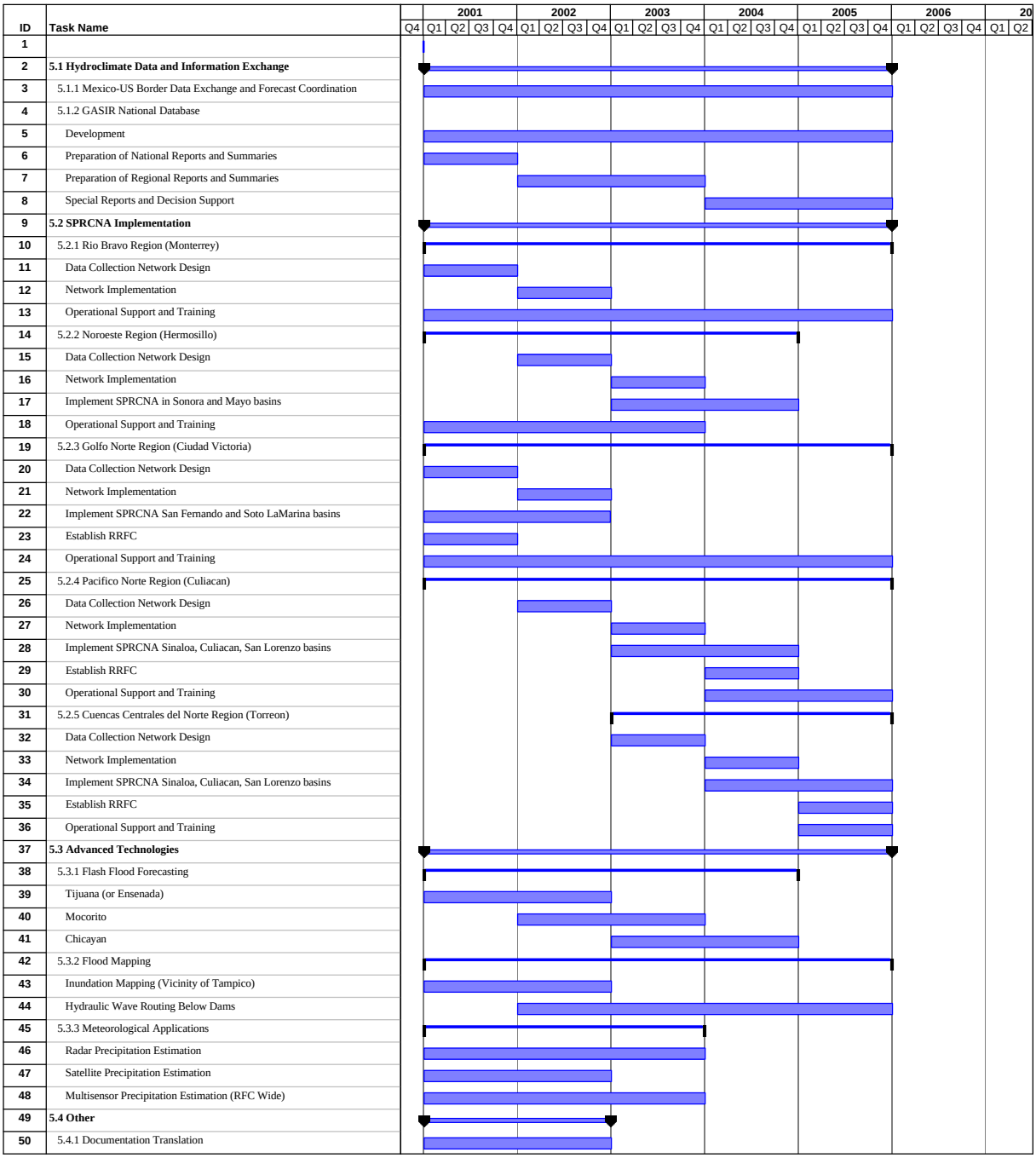

Figure 2 CNA-NWS Project tasks, 2001-2005.

3.0 Project Accomplishments 1996-2000

3.1 Sistema de Pronóstico en Ríos de la CNA (SPRCNA)

Since 1996, the NWS and GASIR have implemented the NWSRFS in the Ríos Fuerte, Yaquí, Pánuco, and Bravo basins, which are shown in Figure 3. The Río Fuerte and Yaquí systems are currently in operation in GASIR headquarters in México City and in the CNA Noroeste RRFC in Hermosillo, Sonora. At the end of 2000, the Río Pánuco SPRCNA will be operational in GASIR headquarters and the Río Bravo SPRCNA will be operational in the CNA Río Bravo RRFC in Monterrey, Nuevo León.

The NWS introduced the NWSRFS in a workshop in March 1997 for 20 PROMMA participants, who represented GASIR, GSMN, IMTA, and the CNA Gerencia de Ingeniería Básica y Normas Tecnicas. The workshop was conducted at the NWS National headquarters in Silver Spring, Maryland. As part of the workshop, the participants visited the NWS Weather Forecast Office (WFO) and River Forecast Center (RFC) in State College, Pennsylvania. The workshop initiated the dialogue between CNA and NWS technical staff about the project, and water-management practices in México and the US.

NWS and GASIR engineers cooperatively developed the NWSRFS in the basins cited above. In order to take advantage of available historical data, they conducted inventories of the data in each of the selected basin. After completing the inventories, the historical data were analyzed and used in the calibration of NWSRFS hydrologic and hydraulic models. Once the models were calibrated, the engineers configured and initialized the NWSRFS for operation. They were trained in every aspect of the system through seminars, lectures, demonstrations, visits to NWS facilities, and working side-by-side with NWS engineers.

3.1.1 Río Fuerte SPRCNA--In early 1997, GASIR selected the Río Fuerte as the prototype basin to implement the NWSRFS. The Río Fuerte basin has a drainage area of approximately 35,000 square kilometers ($km^{2)}$ and is located in the northwest of México in the States of Sinaloa and Chihuahua (see Figure 3). The basin contains three major dams that serve the needs of agricultural and municipal water supply, hydroelectric power generation, and flood control. The system was delivered to CNA in July 1998. Detailed information on calibration and implementation of the system in the Río Fuerte along with other aspects of the task can be found in NWS, 1998a and 1999c and RTI, 1997a and 1998a.

3.1.2 Río Yaquí SPRCNA--In mid 1998, the NWS and GASIR initiated the implementation of the NWSRFS in the Río Yaquí basin. The basin has a drainage area of approximately 70,000 km^2 and is located in the States of Sonora and Chihuahua. There are four reservoir in the basin that are used for irrigation, flood control, hydroelectric power generation, and other purposes. The system calibration and initialization was completed at the end of 1998 and delivered to CNA in December. Detailed information the implementation can be found in NWS, 1998c and RTi, 1998b.

3.1.3 Río Bravo SPRCNA–The Río Bravo NWSRFS implementation was undertaken in 1999 and 2000. This task is unique to this project because the river is the boundary between the US and México. The drainage area of the basin below Ciudad Juarez-El Paso is about 335,000 km^2. The river is managed under the terms of a treaty between the US and México, which is administered by Comisión Internacional de Límites y Aguas (CILA) and the International Boundary and Water Commission (IBWC). CNA and the NWS coordinated their development activities with the IBWC/CILA. To implement the system, the CNA and NWS are establishing coordination between the NWS West Gulf River Forecast Center (WGRFS) in Fort Worth, Texas and the Río Bravo RRFC in Monterrey, Nuevo León. The Middle Río Bravo system was implemented in 1999, and the Upper and Lower Río Bravo systems are being implemented in 2000.

Figure 3 Sites of the Ríos Fuerte, Yaquí, Pánuco, and Bravo basins

3.1.4 Río Pánuco SPRCNA–The Río Pánuco NWSRFS was implemented in 1999 and 2000. In contrast to the other basins discussed above where NWS engineers in the US undertook most development tasks, CNA engineers in México undertook most development tasks with the assistance of NWS engineers. The basin has a drainage area downstream of México City of about 100,000 km^2 and has unique hydrologic and hydraulic characteristics, especially in the coastal sub basins where the land is very flat and the river is highly influenced by the Gulf of

México tidal effects. Due to the complex hydraulic characteristics of the downstream reach, the NWS assisted CNA use a dynamic flow routing model of the area. The assessment of the technique can be found in Riverside Technology Inc. (RTi) 1999b. GASIR engineers began to implement the system in Río Pánuco in 1999 and will complete the implementation in 2000 (RTi, 2000c).

3.2 Development and Implementation of Advanced Technologies for River and Flood Forecasting

In support of flood and river forecasting, several advanced technologies were implemented by the project. These include evaluation of precipitation estimation using radar and satellite images, application of GIS to visualize of the extent of flooding and for damage assessment, and development of a database management system that automates the storage and flow of real-time hydroclimate data.

3.2.1 Precipitation Estimation--Precipitation data are the most important input to the NWSRFS and traditionally are derived from gage networks. The scarcity of gage data in México forced the CNA and NWS to evaluate other sources of precipitation data. Although radar and satellite data have inherent bias in precipitation estimation, such data provide spatial and temporal estimates of precipitation fields that are not possible from rain gage networks. Radar and satellite techniques also can be used to estimate precipitation over oceans and uninhabited land.

3.2.1.1 Use of Radar in Estimating Precipitation--In 1997, NWS and CNA experts met to examine the weather radar network in México, and prepared a plan to use Guasave radar data for this purpose and use these estimates as input to the Río Fuerte NWSRFS (Georgakakos, 1997). In 1998, the GSMN, NWS, and IMTA convened another meeting which concluded that the Guasave radar, which needed to be upgraded, was inappropriate for precipitation estimation and that the Ciudad Obregón radar was more appropriate to demonstrate the use of radar in the Río Yaquí basin (HRC, 1998). This task continues in 2000.

3.2.1.2 Use of Satellite Imagery in Estimation Precipitation--In 1999, the NWS, GSMN, and IMTA conducted a test to evaluate the use of satellite imagery to estimate precipitation. Using three different satellite estimation techniques, including the Estimación de Precipitación Pluvial en México (EPPrepMex) technique developed by IMTA, the satellite estimated precipitation were compared with gage data. The comparisons were made as point and mean areal estimates of precipitation. The test provided promising results, concluding that satellite imagery can be used as another source of precipitation estimation. Detailed information is found at Fortune and Tokar, 2000, and NWS, 2000b.

3.2.2 Flood Inundation Mapping using GIS--In 1998, the NWS and GASIR visited the major reservoirs and San Blas in the Río Fuerte basin to evaluate the application of GIS flood inundation mapping in the area. Based on the trip, the team concluded that the San Blas area was not suitable for GIS mapping and GASIR recommended the Río Pánuco as an alternative. In

1999, the NWS prepared the framework of a GIS based flood inundation map based on probabilistic Río Pánuco flooding in the Tampico area (NWS, 1999b). The system uses probabilistic river forecasts from the NWSRFS and displays the results on a map. In December 1999 CNA-NWS meeting, the NWS gave a demonstration of a hypothetical scenarios of flood inundation of Tampico using GIS technology. The NWS is continuing to develop software, which will use high resolution DEM data and updated databases, to map flood extent.

3.2.3 Hydroclimate Database Management Systems--In 1998 and as part of the PROMMA goal of decentralizing water management, the NWS and CNA reviewed the exchange of data and information among the CNA Regional offices and headquarters, and gained insight into the need to exchange hydroclimate data and forecast information. A team of NWS and GASIR representatives visited the Noroeste and Pacifico Norte CNA Regions and met with the users of CNA products later in the year. In 1999, the NWS began to develop a prototype Internet-based system to facilitate the exchange of information between Hermosillo and México City (RTi, 1999b). The NWS implemented the first version of this system in GASIR headquarters and in Noroeste Region, Hermosillo. Detailed information on database applications and exchange of data and information between México City and Noroeste Region can be found in RTi, 1999a, Curtis, 1998a, and NWS, 1998f.

3.2.4 Dynamic Flow Routing using the FLDWAV model for Río Pánuco--As cited in Section 3.1.4, the coastal portions of the Pánuco basin has highly complex hydraulic characteristics. In 1999, NWS and GASIR representatives visited Tampico to discuss these characteristics with CNA Golfo Norte Regional staff, who provided information on the general hydraulic characteristics of the river, maps of hydrologic stations, and information about flood-prone areas of the Tampico area (RTi, 1999a). In 2000, NWS and GASIR representatives also met with Comisión Federal de Electricidad (CFE) project office in Querétaro to assure that there is no duplication of effort in modeling of the lower Río Pánuco that (a) CFE is undertaking for CNA for planning purposes using the ISIS hydraulic model and (b) NWS is undertaking for forecasting purposes using NWSRFS models. The CFE provided river cross-sectional data, and ISIS inputs and documentation to the NWS. The NWS and CNA are implementing FLDWAV in hydraulic regimes of the basin in 2000.

3.3 Regional River Forecast Centers

Decentralization of the water management in México is an important PROMMA goal. In 1998, the NWS and GASIR met with CNA Noroeste and Pacífico Norte Regions to define the organization and staffing of a prototype RRFC. As a result, the NWS prepared two reports: one documenting CNA policy and schedule for decentralizing authority from headquarters to the regions and the other documenting current GASIR's practices, and modernization and decentralization plans (Martínez, 1998a and 1998b). Within the guidance of these reports, the NWS prepared documents that summarized the technologies and human resources needs of CNA to operate river and flood forecasting technology in the Regions (Curtis, 1998a and 1998b).

3.3.1 Noroeste Region–The Noroeste Regional headquarters in Hermosillo, Sonora, will become responsible for river forecasting in the Río Yaquí basin. Based on Regional requirements defined in 1998, the NWS and CNA installed a scientific workstation and database in the Regional headquarters in 1999, and trained Regional staff in Río Yaquí SPRCNA operation. The NWS also began development of an Internet-based system to exchange data and information with a GASIR database in México City. The CNA will provide the Region with a second workstation in 2000 and a more complete system to store and exchange information with México City.

3.3.2 Río Bravo Region–The Río Bravo Regional headquarters in Monterrey, Nuevo León, will become responsible for river forecasting the Río Bravo. By the end of 2000, CNA will provide this Regional office with two scientific workstations and a database, which will provide the technology to operate the Río Bravo SPRCNA when it is complete at the end of 2000. This is an especially important responsibility because the Río Bravo is a boundary river and close coordination among the CNA, CILA, IBWC, and the NWS is required to forecast and manage the river, and meet binational treaty requirements.

3.4 Capacity Building and Development of Human Resources

Training and cooperative development are very important aspects of this project, if the technology is to be sustainable after the conclusion of the project. In contrast to training, which provides lectures on the structure and operation of the system, cooperative development provides CNA engineers and scientists with on-the-job experience with US counterparts on all aspects of NWSRFS implementation.

3.4 1 Training and Cooperative Development--The GASIR and NWS strongly emphasized capacity development of CNA engineers on the NWS river and flood forecast, and other related technology. Selected engineers from GASIR, IMTA, and CILA undertook cooperative development with NWS counterparts during the implementation and calibration of the Ríos Fuerte, Yaquí, and Bravo forecast systems. Each engineer participated in three, month-long training and cooperative development sessions at RTi facilities in Fort Collins, Colorado for one of these river basin systems during 1997 through 1999. In 2000, the CNA and NWS adopted a advanced professional development approach, wherein each CNA engineer who has participated in implementing the NWSRFS in a river basin will spend two or more month-long work periods at an RTi facility working side-by-side with RTi engineers. These work sessions were tailored to development responsibilities of the engineer. The intent of this training is to further prepare CNA engineers to work more independently in the future to implement and sustain NWSRFS technology. Detailed information, training topics, and calendars can be found in RTi, 2000a, 1998a, and 1998b. The engineers who were trained in this technology from 1997-2000 are listed in Appendix A.

3.4.2 Study Tours and Water Management Modernization Workshops--The NWS conducted study tours in 1999 and 2000 to exchange information between CNA staff and NWS, US

Geological Survey, and US Army Corps of Engineers staff in border areas. The NWS also conduced three workshops in support of the project. The first one on the NWSRFS was held in Silver Spring, Maryland in 1997, the second one on hydrologic applications of GIS technology was in México City in 1997, and third one on reservoir DSSs was held in México City in 1998. The goal of the workshops was to facilitate exchange of information between the CNA and other US Federal agencies, organizations, universities, and private sectors that can assists CNA with the other water-resources management and modernization needs under PROMMA.

3.5 Other Activities

A number of other CNA-NWS activities were undertaken that strengthened the technical basis of the project. Border data and information exchange only began in 2000, and takes advantage of a database development and Internet-based data exchange activity that has been undertaken to strengthen data management between GASIR headquarters and CNA regions. It holds promise to be a major undertaking during the 2001-2005 period.

3.5.1 NWSRFS Manual Translation--The NWS began to translate NWSRFS documentation from English to Spanish to make documentation more accessible to CNA engineers, and strengthen training and operational use of NWSRFS in México. The translated documents will be an important reference for GASIR engineers as they continue to implement the NWSRFS in other areas of México. A team of the NWS and GASIR engineers met in 1998 and 1999 to review the translated documents and ensure the Spanish technical terminology used in the translation is compatible with CNA's terminology. As the documents are translated they are made available to CNA staff directly and via the Internet.

3.5.2 GASIR/NWSRFS Model Comparison--The NWS and GASIR conducted a task to further understand the strengths and weakness of the GASIR MODCA model and NWSRFS models. Strict comparison of both models was inappropriate due to difference in applications and assumptions made in model development. More information on model comparison task can be found on 1998 Annual Report (NWS, 1998a).

3.5.3 Border Data and Information Exchange--In 1999, CNA and the NWS agreed that officials on both sides of the México-US border would be better prepared to manage hurricanes and floods if they had more complete real time hydroclimate data and forecast information from both sides of the border. Towards that goal, the database management system that is discussed in 3.2.3 above will be used to store data and information from the NWS West Gulf River Forecast Center (WGRFC) and other US sources, and will forward Mexican data and information to selected US organizations.

3.5.4 Coordination With Other Related PROMMA Projects--PROMMA concerns modernization of numerous aspects of water management and many management groups in CNA, and international and commercial organizations are implementing aspects of it. In particular, the World Meteorological Organization (WMO) is assisting PROMMA redesign and

automate data collection networks in priority basins in México. Through the PROMMA office, the NWS and WMO are coordinating their assistance to CNA. In December 1999, both organizations assisted the Subdirección General Técnico and PROMMA office brief CNA national and Regional staff on PROMMA.

3.6 Summary of Project Accomplishments

During 1996-2000 CNA staff became introduced to and developed competence in NWSRFS forecasting and associated technologies, and NWS staff became familiar with CNA hydroclimate data collection and management practices. During the development of the four SPRCNA's, CNA staff knowledge of the sources and characteristics of hydroclimate data added greatly to inventorying, quality assuring, and using the data to calibrate NWSRFS hydrologic and hydraulic models. Staff from both countries gained considerable familiarity with data-collection and water-management practices, and technologies in use in both countries, which will provide a base for continued cooperation between CNA and the NWS.

4.0 Recommendations and Assumptions

The recommendations and assumptions included below are based on the experiences gained during 1996-2000 that are documented in each year's annual report. They also reflect the emergence of new technologies that are now available for use by the project. In addition they are responsive to the needs of decision makers as they work to mitigate loss of life and property caused by floods and to better manage water resources, now and in the future. The recommendations and assumptions concern capacity development of CNA staff, hydroclimate data and information exchange, the geographic extent of technology implementation, data-collection networks, use of the Internet, and implementing flash flood technologies.

4.1 Capacity Development

Development of CNA staff capacity is critical to assure that flood forecasting and associated technologies will continue beyond the completion of this project. Before 2000, CNA staff were introduced to NWSRFS technology by participating in implementing the technology in particular river basins. In 2000, the project provided advanced professional development to engineers who were familiar with the technology, but needed a higher skill level to sustain the technology and assist Regional staff who would become responsible for implementing and operating advanced technologies. Advanced professional development is needed beyond 2000 in order to strengthen GASIR staff support to CNA regions as they implement NWSRFS, database, Internet, and other advanced technologies. This will assure that CNA can meet its responsibilities as a center of technology transfer from CNA headquarters to CNA regions.

4.2 Hydroclimate data and information exchange

The CNA and NWS data-exchange efforts serve to facilitate the exchange of hydroclimate data

and forecast information between CNA Regional offices and a GASIR database in México City and between the GASIR database and counterpart databases in the US that contain border data and information. The former improves CNA's ability to analyze current conditions in México and strengthen decision support for operation of Federal reservoirs for flood control, agricultural and municipal water supply, environmental protection, and hydroelectric power production. The latter improves CNA's ability to monitor conditions in the border area of the US, which is especially important during hurricanes and floods. The CNA and NWS should continue to implement advanced database technology in order to establish technical protocols for the long-term exchange of data both within Mexico and between Mexico and the US.

4.3 Geographic extent of technology implementation

CNA-NWS cooperation have successfully implemented the NWSRFS in four basins. Additional NWSRFS is needed to enhance technical competencies of GASIR and regional staffs. Additional basins in the north of Mexico have been identified for NWSRFS implemnetation as detailed in section 5 below.

4.4 Data collection networks

The NWSRFS implementation in basins during 1996-2000 used existing historical data for model calibration. CNA and NWS should review the hydroclimate networks and identify where additional real-time hydroclimate stations should be established to strengthen flood forecasting and river management. The NWS also should provide technical assistance to CNA to procure, install, and maintain automated networks, and develop CNA staff capacity.

4.5 Networking and communications

Networking and communications technologies, including local networks, wide area networks, and Internet communications are vital to the sustainability of the data collection and forecasting programs being implemented by this program. These technologies are particularly important tools for information exchange between (a) GASIR in México City and CNA Regions, (b) CNA and water and weather organizations in the US, and (c) CNA and the public. As this tool becomes more integrated into CNA operations, it is critical that CNA staff become more sophisticated in its use. CNA offices must ensure that the communications provide secure access. Towards those goals, the NWS and CNA should:

- establish local area networks and services at GASIR offices at Av. Insurgentes Sur No 30 and Av. Observatorio No 192 in Mexico City.
- ensure GASIR staff become responsible for network and communications maintenance and support, and receive training in local area and wide area network administration, UNIX system administration, and Internet Protocol network communication.
- establish permanent connections to the Internet for GASIR offices cited above, via

the CNA telecommunications network.

4.6 Flash flood basins

Flood forecasting technologies that CNA and NWS have implemented to date are most appropriate for large river basins. However, many people in México are at risk to flash floods that occur in small river basins. During 2001 - 2005 period, CNA and NWS should demonstrate flash flood and warning technology in selected small river basins in México.

5.0 Future Activities, 2001-2005

In anticipation of the renewal of the SEMARNAP-NOAA agreement, during 2001-2005, the two organizations intend to continue a program of technology transfer that builds on past successes and incorporates new technologies. Additional activities are planned for the CNA Río Bravo, Noroeste, Golfo Norte, Pacifico Norte, and Cuencas Centrales del Norte Regions as follows:

- Río Bravo Region--development will concern coordination of data and forecast information exchange in the border area, strengthening the capacity of the staff in the RRFC that is being implemented in 2000 in Monterrey, Nuevo León, and operational implementation of improved satellite precipitation estimation,
- Noroeste Region--the RRFC in Hermosillo, Sonora will be strengthened, additional river basins will be implemented, and radar precipitation estimation will be integrated with the river forecast system.
- Golfo Norte–development will concern establishment of an RRFC in Tampico or Altimira, Tamaulipas, implementing additional river basins, strengthening the use of the Río Pánuco SPRCNA, and completing flood mapping in the vicinity of Tampico,
- Pacifico Norte and Cuencas Centrales del Norte Regions--principal river basins will be implemented and RRFC's will be established in Culiacan, Sinaloa and Torreón, Coahuila, Sinaloa.

At the end of this period, river forecasting and associated technologies will be in operation in numerous basins in the northern half of México and the capacity and professional development of CNA staff will be sufficient to continue implementation of these technologies elsewhere in México. During this five-year period, CNA staff will continue to strengthen their personal and professional relationships with counterparts in the NWS and other water agencies, and the private sector, which will allow them to participate in strengthening water management practices in México and the US. Project tasks during this time will concern hydroclimate data and information exchange development, and implementing the SPRCNA, data-collection networks, installation of RRFC's in additional river basins in northern México. Task also will concern other advanced technologies related to flash-flood, flood mapping, and meteorological applications, and translation of NWSRFS documentation from English to Spanish.

5.1 Hydroclimate Data and Information Exchange

Development of hydroclimate databases and data transfer via the Internet will serve two purposes in México to strengthen: México-US border data exchange a forecast coordination and GASIR's ability to assess hydroclimate conditions in México.

5.1.1 México-US Border Data Exchange and Forecast Coordination–The technology base of this activity will be provided for by sections 5.1.2, GASIR National Database, and 5.2.1 Río Bravo Region that are discussed below. Database and Internet development will provide the mechanism to acquire data from selected on-line databases in the US that contain data of interest to CNA, and transfer selected CNA data to counterparts in the US. These data will be exchanged frequently and automatically so that they will be available at all times, and especially during hurricanes and floods. The exchange also will facilitate coordination of Río Bravo forecasting between the NWS WGRFC and CNA Río Bravo RRFC under section 5.2.1. This activity also will sponsor meetings of water officials in the border areas of both countries, so that they can review annually the data and information being exchanged, discuss emergency management contingency planning, and improve coordination of water management under the auspices of CILA and IBWC. An important goal would be the development of jointly prepared technical protocol for data exchange and river forecasting coordination.

5.1.2 GASIR National Database–This activity initially is intended to facilitate the exchange of data and information between México City and Hermosillo, Sonora, and Monterrey, Nuevo León. By 2002, the database and Internet access will have been sufficiently tested to support the exchange of data and information between México City, and all CNA Regional and State offices. Eventually, CNA plans to phase out the current GASIR database that resides on personal computers and replace it with the one under development. The new database will facilitate the preparation of hydroclimate analyses, reservoir analyses, and other National and Regional reports that are needed to assist CNA decision making.

5.2 Sistema de Pronóstico en Ríos de la CNA (SPRCNA)

Implementation of SPRCNA will continue in five CNA regions in northern México. CNA is making the transition from a largely manual data-collection network that provides daily measures of precipitation and river flow in these regions, to automated networks that collect data as frequently as several times per hour and transmit data several times per day. In each region, NWS and CNA will review the current hydroclimate network design, determine the need to acquire additional real-time data for flood forecasting and river management, and implement a strategy for strengthening the network. This strategy will concern preparation of technical specifications, procurement, installation, and maintenance of equipment, and CNA staff capacity development. The NWS and GASIR staff in México City will assist Regional staff implement the NWSRFS in selected basins that are listed in section 5.2.2 through 5.2.5. In regions where RRFC's have been implemented, the NWS and CNA will provide support to assist Regional staff operate, maintain, and improve SPRCNA's, and solve problems as they

occur. In regions where RRFC's have not been implemented, the NWS and CNA will assist in establishing them, then provide assistance in RRFC and SPRCNA operation, maintenance, and improvements. The Regions will participate in activity 5.1.2, GASIR National Database, and assist in the development of a standard suite of Regional-level reports. Additionally, the CNA and NWS intend that staff in each region will be sufficiently trained to prepare additional Regional reports that are required by and are unique to the region.

5.2.1 Río Bravo Region will be responsible for operating the Río Bravo SPRCNA, contribute much of the data and information for trans-border exchange, coordinate forecast information with the WGRFC, and assist CILA and IBWC meet border treaty requirements. As a border region, it will participate in exchange of visits between CNA and counterpart staff in the US to strengthen data and information exchange, and improve emergency contingency planning.

5.2.2 Noroeste Region will operate the Río Yaqui SPRCNA, implement the Sonora and Mayo SPRCNA's, and exchange data with the NWS Colorado Basin River Forecast Center (CBRFC) and other US organizations. As a border region, it will participate in exchange of visits between CNA and counterpart staff in the US to strengthen data and information exchange, and improve emergency contingency planning.

5.2.3 Golfo Norte Region will operate the Río Pánuco SPRCNA, develop an RRFC in Tampico or Altamira, implement the San Fernando and Soto LaMarina SPRCNA's, and assist in the implementation of GIS flood mapping in the vicinity of Tampico.

5.2.4 Pacifico Norte Region will operate the Río Fuerte SPRCNA, develop an RRFC in Culiacan, and implement the Sinaloa, Culiacan, and San Lorenzo SPRCNA's.

5.2.5 Cuencas Centrales del Norte Region will develop an RRFC in Torreon and implement the Nazas and Aguanaval SPRCNA's.

5.3 Advanced Technologies

NWSRFS technology is appropriately used to forecast and manage large river basins where the response of a river to a major precipitation event is measured in days or weeks. Because there are many basins in México where rivers respond in a matter of hours to intense rain, in the future the project will implement technology that is appropriate to this type of flooding. Visualization of NWSRFS forecasts and use of meteorological data systems also are being used increasingly in the US to strengthen flood forecasting and river management. To varying degrees, all of these technologies will continue to be developed in 2001-2005.

5.3.1 Flash Flood Forecasting and Warning–Flash floods place life and property at risk if warnings are not issued immediately. In the US numerous so-called ALERT (Automated Local Evaluation in Real Time) systems have been installed in small, quickly responsive river basins, especially where there is risk to human life. In recent years operators of these ALERT systems

have organized themselves into Regional groups and a national user group, and have attracted support from numerous suppliers of equipment. This activity will design and install flash flood systems in three basins in México as shown in Figure 4, and strengthen the liaison between

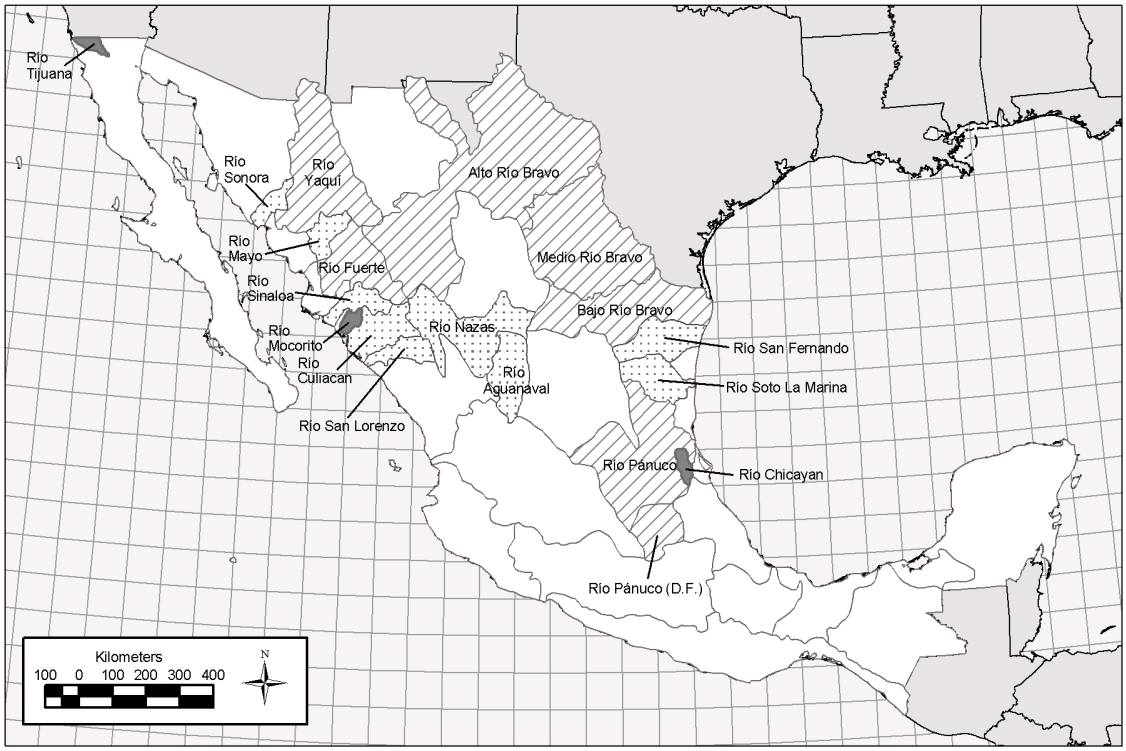

Figure 4 Locations of river basins where flood forecasting technologies are being implemented, as discussed in Sections 3.1, 5.2, and 5.3

Mexican and US users of this technology. The NWS will assist CNA staff at the National and Regional levels, as appropriate, via training and cooperative development. Together, they will determine local requirements, design the systems, assist in procurement, installation, and maintenance of remote-site equipment and base equipment, and strengthen flood warnings.

5.3.2 Flood Inundation Mapping–The integration of GIS and river forecasting technology provides the opportunity to visualize the effects of river floods, either from natural flooding or from releases from large reservoirs. In both cases, the quality of the visualization is dependent upon two issues, the quality of the flood forecast and the quality of the DEM In the case of natural flooding, the CNA and NWS are preparing to integrate the development of the Río Pánuco SPRCNA and GIS technology so that the area to be inundated in the vicinity of Tampico, Tamaulipas, can be visualized. In the case of releases from large reservoirs, the two organizations will simulate a series of large releases from selected reservoirs to visualize effects downstream. In the extreme, the organizations will simulate maximum releases to assess the maximum possible effect.

5.3.3 Meteorological Applications–Applications of meteorological technology for river management and forecasting will continue. Precipitation estimation by radar and satellite will continue, via integration of these data with gage data. In both cases, gage data are required to remove bias because radar data tend to underestimate precipitation and satellite data tend to overestimate precipitation. In addition, the WGRFC is evaluating a new visualization technique that provides all three estimates to be combined in one analytical tool known as RFCWide. The applicability of this tool will be evaluated in CNA Regions. The NWS will assist CNA achieve better, sustained, utilization of its existing radar network in order to augment rainfall information from a sparse network of ground stations.

5.4 Other

5.4.1 NWSRFS Manual Translation–Translation of NWSRFS and other technical documentation will be completed early in the 2001-2005 period and the entire NWSRFS manual will be available on the Internet in Spanish.

6.0 Summary

For several decades, the GSMN and NWS have cooperated on meteorological technology and data collection. Beginning in late 1996 and continuing through 2000 the CNA and NWS have cooperated on hydrological technology and data collection, in particular the transfer of technologies required for river forecasting and management. During the period, river forecasting technology has been implemented in the Ríos Fuerte, Yaquí, Bravo, and Pánuco basins in México. Associated technologies that concern precipitation estimation by satellite and radar have been evaluated and are beginning to be applied, along with techniques for visualizing the extent of flooding. Systems to automate hydroclimate data Internet transfer, and storage and retrieval have been installed in CNA and will be used to facilitate the exchange of hydroclimate data and river forecast information between GASIR headquarters and CNA Regions. These systems will support México-US data and information exchange, which will better prepare both countries to respond to hurricanes and flooding that take place in both countries.

Based on the 1996-2000 experience, the CNA and NWS plan to continue to apply river forecasting technology in other major river basins in northern México and flash flood and warning systems will be implemented in selected basins. The project will continue the implementation of database and Internet-based technologies for domestic and international data and information exchange. Meteorological and visualization applications in support of river forecasting and management also will be continued. Finally, a major legacy of this project will be the strengthened professional relationships between CNA professionals and their counterparts in the United States. This will facilitate the cooperation on solving bi-national technology problems and provide support to CILA/IBWC as they manage boundary water issues.

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8.0 Acronyms

The following acronyms appear in this report.

ALERT	Automated Local Evaluation in Real Time
CBRFC	Colorado Basin River Forecast Center
CILA	Comisión Internacional de Límites y Aguas
CNA	Comisión Nacional del Agua
DCP	Data Collection Platform
DEM	Digital Elevation Model
EPPrepMex	Estimación de Precipitación Pluvial en México
FLDWAV	Flood Wave (hydraulic model)
GASIR	Gerencia de Aguas Superficiales e Ingeneria de Ríos
GIS	Geographic Information System
GOES	Geostationary Operational Environmental Satellite
GSMN	Gerencia de Servicio Meteorologico Nacional
HIF	Hydrologic Instrumentation Facility
HRAP	Hydrologic Rainfall Analysis Project
HP	Hewlett Packard
IBWC	International Boundary and Water Commission
IG-DB	Integrated GASIR Database
IP	Internet Protocol
IMTA	Instituto Mexicano de Technología del Agua
MAP	Mean Areal Precipitation
NASA	National Aeronautics and Space Administration
NESDIS	National Environmental Satellite, Data, and Information Service
NOAA	National Oceanic and Atmospheric Administration
NOHRSC	National Operational Hydrologic Remote Sensing Center
NWRFC	Noroeste River Forecast Center
NWS	National Weather Service
NWSRFS	National Weather Service River Forecast System
PII	Pro International, Inc.
PIP	Project Implementation Plan
PROMMA	Programa de Modernización del Manejo del Agua
RBRFC	Río Bravo River Forecast Center
RFC	River Forecast Center
RRFC	Regional River Forecast Center
RTI	Riverside Technology inc.
SGT	Subdirección General Téchnico
SHEF	Standard Hydrologic Exchange Format
SIGA	Sistema Geográfico de Información del Agua
SPRCNA	Sistema de Pronóstico en Ríos de la CNA
UAM	Universidad Autónoma Metropolitana
USGS	U.S. Geological Survey
WGRFC	West Gulf River Forecast Center
WMO	World Meteorological Organization

Appendix A CNA engineers trained on the NWSRFS

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Ing. Francisco Gomez	IMTA	Río Bravo